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THERMAL INSULATION BY INJECTION OF UREA FOAM IN BUILDING STRUCTURES

COLD REGIONS RESEARCH AND
ENGINEERING LABORATORY

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THERMAL INSULATION BY INJECTION OF UREA FOAM IN BUILDING STRUCTURES

National Swedish Board of Urban Planning

CORPS OF ENGINEERS, U.S. ARMY
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
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This report gives information concerning improvement of thermal insulation in existing buildings by injection of urea foam in hollow portions of the structures. When performed and used correctly, insulation with urea foam can result in considerably improved thermal insulation, both in structures with high heat transfer coefficients (K-values) and in structures where the thermal insulating capability is impaired by air flow through fissures and slits.

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1. GENERAL ASPECTS ON INJECTION OF THERMAL INSULATION MATERIALS.

The thermal insulation in existing buildings may for various reasons require improvement. In structures containing hollow portions or spaces this can be accomplished by injection, i.e. spraying or blowing, of insulation material, provided that the hollow spaces are not needed for protecting the structure against moisture (cf., SBN 67 32:31). Wet or dry materials can be used for injection.

An example of wet materials is urea foam, while dry injection materials may consist of mineral wool fibres or granules of cellular polystyrene plastic. From a technical standpoint, the choice of insulating material depends on factors such as the thickness of spaces to be insulated, possibilities for simple drilling and repairing of injection holes, as well as the injection pressure which the structure can withstand. In the case of wet insulation materials, one must consider the capability of the structure to allow moisture to evaporate from the insulation (cf., SBN 67 32:31). Wet insulation materials should therefore only be used in hollow spaces where the colder wall (as a rule the outer wall of the hollow space) does not contain materials that prevent or seriously obstruct penetration of water vapor.

The following discussion will be limited to injection of urea foam, since many unsuccessful insulation tasks have been performed with this material. However, when performed and used correctly, insulation with urea foam can result in considerably improved thermal insulation, both in structures with high heat transfer coefficients (k-values) and in structures where the thermal insulating capability is impaired by air flow through fissures and slits.

2. INJECTION OF URETHANE FOAM.

2.1 Manufacture and Material Properties.

Urea foam is manufactured from a urea-formaldehyde resin which is mixed with water, urea, foaming agents and hardener. The hardener and the other materials are mixed during the injection, which is performed with special equipment. After injection, the foam cures relatively fast and hardens.

Urea foam has open cells and can be made with various densities. When injected into building structures, the foam obtains a density between 7 and 10 kg/m^3. The structural strength is low.

During hardening, the material will shrink, which causes cracks. The curing rate, as well as the rate and amount of shrinkage, are determined by chemical and physical factors. The ratios between the various base materials are critically important, as well as the hardness (calcium content) in the water used to dissolve these materials. If temperatures below 0^oC occur in the space where injection is made, there is considerable risk for inferior insulation performance, even if heated material is used.

Laboratory tests have been performed by the Board, to clarify the shrinking process in urea foam. Three Swedish firms with good experience in injection of urea foam took part in these tests by supplying a number of sample wall

sections injected with urea foam. The density of the injected foam in samples supplied by the three firms was 12, 14, and 23 kg/m^3, respectively. The samples were allowed to dry out in a heated room. From the tests it was evident that approximately the same amount of shrinkage occurred in the three types of samples and that the shrinkage had virtually ceased after one year of storage. The cracks formed in the samples indicated a linear shrinkage of 8 to 10 percent.

Urea foam has a capillary suction capability and can, when subjected to water pressure, absorb large amounts of water. After drying out, the moisture ratio of the material is about 8 percent by weight at an ambient air relative humidity of 35 percent and about 15 percent by weight for an ambient air relative humidity of 85 percent.

The water vapor diffusion coefficient for urea foam without cracks is about 0.05 g/m h mm Hg for a density of 25 kg/m^3. However, the cracks caused by shrinkage will strongly reduce the diffusion resistance of a foam insulation layer.

Completely dried urea foam with no cracks and a density between 7 and 14 kg/m^3, has a heat conductivity that varies from 0.030 to 0.035 kcal/m h^{o}C, for a mean temperature of +10^{o}C in the sample. Due to normally present moisture in the material and convection through the cracks created by shrinkage, the thermal insulation performance is reduced to about one half of that valid for dry material with no cracks. Thus, the effective thermal conductivity can, in practice, be assumed to be about 0.06 kcal/m h^{o}C for urea foam injected into building structures.

Hardened urea foam is combustible but self extinguishing. It will decompose thermally at +200^{o}C. The material is not attacked by fungus, and provides no nourishment for rodents or insects. If the correct amount of hardener (acid) is used, the urea foam will not cause corrosion of nails or other metal parts of the structure.

2.2 Applications

Since the cracks caused by shrinkage has a considerable effect on the insulation performance, injected urea foam should only be used as added insulation in existing buildings in need of improved insulation.

Injection is allowed only in spaces where the drying out process is not impaired by vapor tight materials (cf., the introductory section and SBN 67 32:31). Particularly difficult drying-out conditions are often at hand in floor structures and low attics.

Injection may not be made in a manner which blocks air passages necessary for proper moisture removal from the structure (c.f., SBN 67 32:21).

In areas where exterior walls often are subjected to rain in combination with high winds (heavy rains in exposed locations), urea foam should not be injected inside wooden sheathing and/or siding, unless these are impregnated. It has shown that rot may occur in wooden sheathing or siding under adverse drying-out conditions.

2.3 Work Procedures.

Insulation projects involving urea foam should be carried out according to a work procedure established in advance and which takes into account the recommendations listed in this section.

To prevent damage to the building structure and to ensure that the properties of the final foam plastic material are satisfactory, the following rules must be adhered to when injecting the foam:

(a) Before injection is begun, the building structure must be investigated with respect to the size of hollow spaces and the presence of material layers which may prevent the drying process (cf., section 2.2). As a rule, injection should only be done in spaces that are at least 2 cm thick.

(b) The foam ingredients must be mixed with their proper ratios. Base materials in powder form should be weighed and be allowed to dissolve in water for an adequate time (24 - 48 hours) before injection. The hardness of the water (calcium content) must be selected on the basis of what is suitable for the base materials used.

(c) Injection must be performed only with proper proportions of the various liquids. The pressure must be such that all hollow spaces are properly filled. However, the pressure must not be so high that the integrity of the structure is impaired or other damage occurs. For each hole, injection should continue until foam emerges from neighboring holes.

(d) Injection shall not be performed in weather or other conditions where injected foam may freeze before complete curing, even if pre-heated materials are used.

2.4 Inspection.

The result of a performed injection can not readily be inspected. A certain assurance that a hollow space is completely filled is obtained if the injection in each hole is continued until foam emerges from neighboring holes. In addition, an experienced craftsman can sometimes, by knocking, detect incomplete filling of a space.

The properties of the plastic foam after curing can not be accurately determined at the time of injection. Thus, post-inspection should be performed to ensure that the intended quality of the injected material has been obtained. However, this inspection should not take place until about one year after the injection has been performed.

A suitable method for post-inspection is to uncover small areas of the insulation in randomly selected locations and visually observe its condition. The injection contractor should be present during this inspection. Some crack formation must be accepted, due to the considerable shrinkage of the material.

On the other hand, large voids can not be tolerated and more or less pulverized insulation is not acceptable.

The results of an injection project can also be evaluated by heat flow measurements or by infrared photography. Such measurements must be performed during the cold season and complicated test equipment is required for obtaining reliable results.

CONVERSIONS HELPFUL TO READER

kg/m^3	lb/ft^3
7	.44
10	.62
12	.75
14	.87
23	1.44
25	1.56

kcal/m h °C	BTU·in/hrft²°F
0.030	0.242
0.035	0.282
.06	0.484

°C	°F
10	50
200	392

cm	in.
2	3/4